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Lorentzen, Henrik F.; Benfield, Thomas; Stisen, Simon; Rahbek, Carsten

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## Correspondence

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# COVID-19 is possibly a consequence of the anthropogenic biodiversity crisis and climate changes

Henrik F. Lorentzen<sup>1</sup>, Thomas Benfield<sup>2,3</sup>, Simon Stisen<sup>4</sup> & Carsten Rahbek<sup>5,6,7</sup>

1) Aarhus University Hospital, Department of dermatology, Aarhus, Denmark. 2) Department of Infectious Diseases, Hvidovre Hospital, Denmark. 3) Institute of Clinical Medicine, University of Copenhagen, Copenhagen, Denmark. 4) Department of Hydrology, Geological Survey of Denmark and Greenland, Copenhagen, Denmark. 5) Center for Macroecology, Evolution and Climate, GLOBE Institute, University of Copenhagen, Denmark. 6) Department of Life Sciences, Imperial College, London, UK. 7) Danish Institute for Advanced Study, University of Southern Denmark, Odense, Denmark.

Corresponding author: Henrik F. Lorentzen. E-mail: [lorentzen@dadlnet.dk](mailto:lorentzen@dadlnet.dk)

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Climate change has set the agenda since the UN Climate Change Conference (COP-25) but has nearly disappeared from public debate following the outbreak of the Coronavirus Disease 2019 (COVID-19) pandemic. Also, the world was heading to China, later this year, for the UN Convention on Biological Diversity to discuss a “Paris-agreement” for biodiversity to deal with the global biodiversity crises, with mass-extinction of species, wildlife-trade (e.g. the marked in Wuhan) and disturbance of up to 70% of the Earth’s natural ecosystems [1]. Disturbance of natural ecosystems has been reported to increase the transfer of disease from wild species to humans and is suggested as the principle cause of the increase in occurrences of neglected, forgotten and new human diseases [2].

The world’s focus is currently on the COVID-19 pandemic. However, we think that the relationship between this new disease, climate changes and reduction in biodiversity may be interrelated at a deep and troublesome level, that requires urgent attention.

It is well-established that bats are the reservoir for several viruses capable of species-crossing, evident by recent outbreaks of related viruses including Ebola virus, Severe Acute Respiratory Syndrome (SARS) Coronavirus 1, Middle East Respiratory Syndrome (MERS) Coronavirus, Nipah virus and Hendra virus. While these viruses often cause severe morbidity and mortality in

incidental mammals, bats remain clinically asymptomatic upon infection [3]. It has been suggested that the quiet co-existence of bats and viruses is an immune adaptation to high and prolonged metabolic increase during flight, that would otherwise trigger a detrimental immune response due to, among other things, high levels of free radicals. Elevated basal heat-shock protein expression [3] and the loss of the interferon-inducible protein 20X/16 (PYHIN) protein family [4] which, among mammals, coincidentally only observed in bats, are believed to be important elements of bat adaption to body heat during flight.

While habitat destruction is the main driver of decreasing biodiversity, climate change may play a role by forcing species to shift habitat, change geographical range and to survive in semi-natural habitats that may bring wild animals closer to humans and livestock. Caves, bridges and trees are bats natural habitat. Upon destruction or disturbance of these, species are pressed into increasingly smaller areas, or forced to find new semi-natural habitats that may be in close proximity to humans. In the new environment, bats of different species interact, thereby increasing the risk of transspecies transmission of viral diseases. The same effect, albeit even more extreme, happens at wildlife trade markets such as that in Wuhan, where bats, pangolins, and other animals, that are known to transmit coronaviruses, are crammed together under fetid conditions. Such markets – and bush-meat trade across, e.g., Africa, are largely linked to the global challenge of poverty and ensuring a nutrient diet for billions of people world-wide.

Dissimilar virus species require an intermediate host to facilitate spread to humans. Coronaviruses, that cause SARS, MERS and COVID-19, have bats as their reservoir and may use a number of intermediate hosts, e.g. mongoose, camel, snake, crocodile and ape. Further, bats are the reservoir for Hendra (equine morbilli) [5] and the Nipah viruses, that use horse or pig as an intermediate host. Nipah virus may also be transmitted directly from bats feeding on date palm sap that humans later ingest [6]. Finally, concern has been raised over hunting of bats for human consumption [7].

Rabies (genus *Lyssavirus*, family *Rhabdoviridae*) is another virus where bats are the reservoir. Person-to-person spread of rabies is rare. This is likely because *Lyssavirus* requires close proximity to nerve cells to establish infection, e.g. through biting. Most cases are acquired through deep bites from other mammals and therefore the incidence of rabies may be considered a proxy for the increasing density of bats close to humans. If bat habitats are brought closer to humans, an increase in rabies would be expected. In 1996 the accumulated one-year incidence of rabies in China was 0.0013 per 10<sup>5</sup> population. This increased to 0.1511 in 2003 and coincident with the first SARS epidemic [8]. Cases of rabies were particularly high in and around the epicenter of the first SARS outbreak in the Guangdong province.

Data from the Arabian Peninsula are less comprehensive and information on bat density is not reported [9].

In Saudi Arabia, that was the first epicenter for MERS, one of the world's largest freshwater reserves beneath the desert has been substantially reduced by pumping water to the surface to

grow crops [10] and further aggravated by climate change [11].

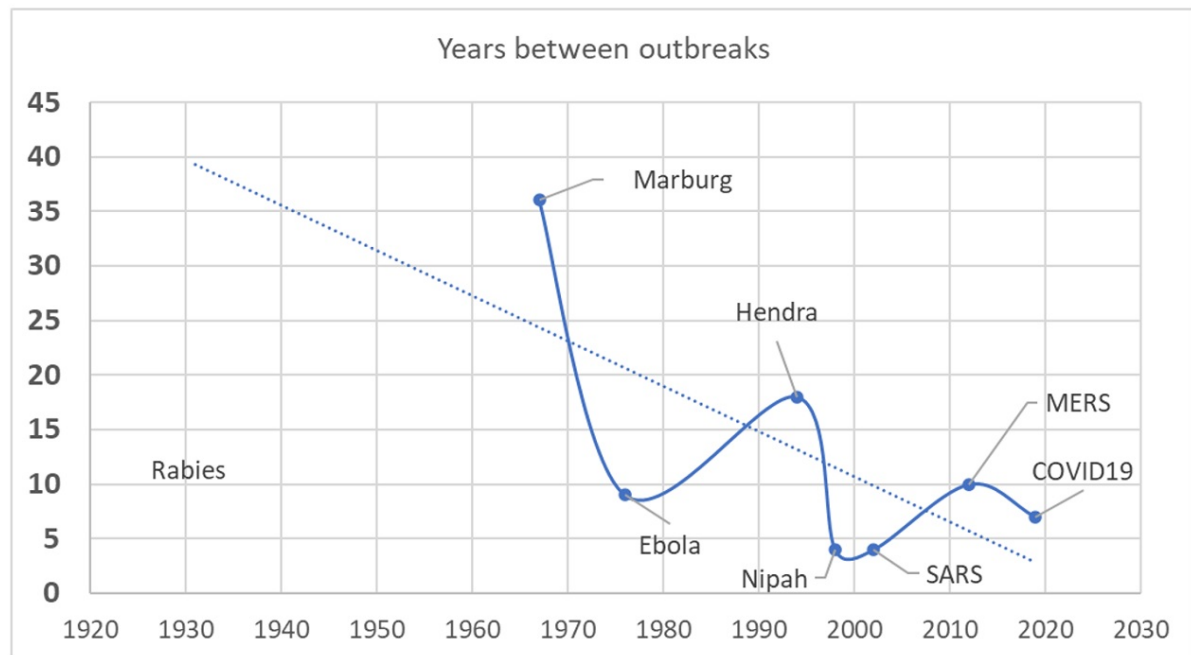
Both North China and Saudi Arabia are global hotspots for groundwater depletion and general decline in terrestrial water storage [12] due to a combination of groundwater overexploitation for food production and climate change [13].

Karst is the dominating geological landscape in large parts of China and the Middle East. Its underground system of caves is the preferred habitat for hibernating cave bats due to the stable temperature and high humidity, that is required to avoid bat dehydration and to provide drinking water [14]. The hydrology of karst systems is particularly vulnerable to ground water depletion and climate change [15].

In addition, the combined anthropogenic pressure on water, due to climate change, water and land management, has led to a marked drop in open freshwater surfaces in China with regards to wetlands [16], lakes and water reservoirs [17].

Humans have decimated the biomass of wild species of mammals (~5500 species) to only 4%, whereas humans and our livestock constitute 96% of mammalian biomass on Earth. For the 11,000 bird species, 70 % of biomass of birds comes from our domestic birds, mostly chickens. From the perspective of microbes, there is one major resource that is abundant, stable and widespread, namely humans. We are witnessing the emergence of novel diseases at an unprecedented rate[2]. In 2003, Epstein and colleagues at Harvard Medical School argued that human-induced changes in ecological systems and climate were triggering “a barrage of emerging diseases that afflict humans, livestock, wildlife, marine organisms, and the very habitat we depend upon” [2].

In Figure 1, we show the interval between first spillover and outbreak of infectious diseases originating in bats. Every single outbreak is an example of chaos theory and therefore unpredictable. However, the interval between spillovers has become shorter and shorter. This is probably due to complex connections between virology, biodiversity, climate changes, poverty, food safety and population growth.



**FIGURE 1:** Years between first spillover and outbreak of various diseases originating in bats. Truncated line: tendency toward shorter intervals between incidents. Rabies was assigned to 1931, the year of the identification of rabies virus in bat brains.

In the economic aftermath of the corona pandemic, there is an emerging debate on whether or not we can afford to invest in sustainable solutions to the global biodiversity-crises and climate-change, that likely are interconnected to the COVID-19 pandemic. It is our opinion that we simply cannot afford not to.

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